International Journal of Modern Physics A

Drell-Yan Production at the Fermilab Tevatron

JEDONG LEE[*] on behalf of CDF and D0 Collaborations
Department of Physics and Astronomy, University of Rochester, 600 Wilson Blvd, NY 14627-0171, USA

Received (Day Month Year)
Revised (Day Month Year)

Using data from $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV collected by the CDF and D0 detectors, we present measurements of the Drell-Yan inclusive differential cross section and forward-backward charge asymmetry as a function of invariant mass. We compare these measurements with Standard Model predictions, and present searches for new physics that could appear as deviations from the Standard Model in the Drell-Yan differential cross section.

Keywords: W boson; Z boson; Drell-Yan; New phenomena.

1. Introduction

Since Run II of the Tevatron started in March 2001, CDF and D0 collaborations have collected data from the $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV. We present results from the analyses of inclusive dilepton final states $e^+e^-, \mu^+\mu^-, e\nu$ and $\mu\nu$. In the Standard Model, these states at high invariant mass are dominated by production of on-shell W and Z bosons. The interactions of these gauge bosons follow the V-A structure, as can be shown from the forward-backward charge asymmetry (A_{FB}). One can probe the parton distribution functions (PDF) from the rapidity distribution of the gauge bosons. Finally, we present search for signatures of new physics in the invariant mass distribution and angular distribution of the lepton pairs.

2. Result on Forward-Backward Asymmetry

In the process $p\bar{p} \to \gamma^*/Z \to l^+l^-X$, the vector and axial-vector couplings of the gauge bosons to fermions give rise to an asymmetry in the polar angle of the lepton momentum in the rest frame of the lepton pair with respect to the proton direction. The differential cross section for $p\bar{p} \to l^+l^-X$ may be writen as

$$\frac{d\sigma}{d\cos\theta^*} = A(1 + \cos^2\theta^*) + B\cos\theta^*, \tag{1}$$

[*]Fermilab, P. O. Box 500, MS318, Batavia, IL 60510, USA

where A and B are constants and θ^* is the scattering angle of the outgoing lepton [4]. A_{FB} is defined as following.

$$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B} = \frac{3B}{8A}, \tag{2}$$

where $\sigma_F(\sigma_B)$ is the cross section for $\theta^* > 0$ (< 0).

Using 72 pb^{-1} of data taken with CDF Run II detector, we selected the events with one tight electron candidate with high transverse energy in the central region of the detector and one additional loose electron candidate in the central or forward region (Fig 1). We divide the dielectron invariant mass into 15 bins, and calculate A_{FB} in each mass bin. Detector resolution and photon radiation from the outgoing electrons smear measured invariant mass and distort the distribution of A_{FB}. In order to unfold the true A_{FB}, we apply a method of regularized unfolding to the raw A_{FB} [4] and perfom a likelihood fit to find the resulting forward-backward asymmetry (Fig. 1). No significant deviation from the theoretical prediction was found in the statistically limited comparison.

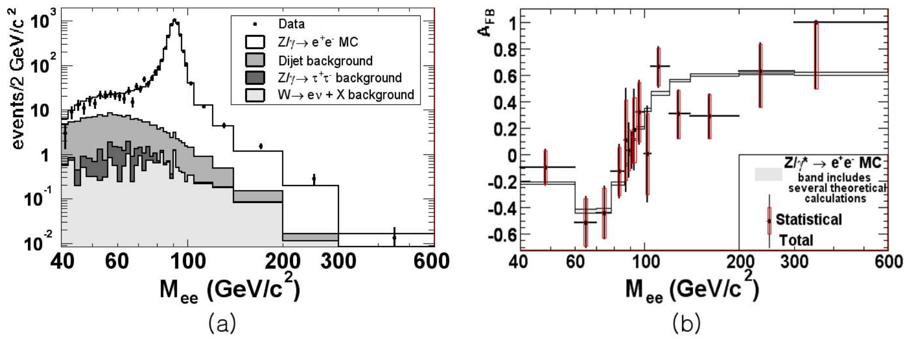


Fig. 1. *(a) Invariant mass of selected data. Shown with Monte Carlo expectation and background estimation. (b) Forward-backward asymmetry result compared with theory band.*

3. Result on W Charge Asymmetry

The rapidity distribution of the W bosons from the $p\bar{p}$ collisions is sensitive to the PDF of the proton. If a u quark from the proton and a $\bar{d}$ quark from the anti-proton produce a W^+, the gauge boson is boosted in the direction of the proton because u quarks carry a higher fraction of the proton momentum. The W^- produced from a d quark from the proton tends to be boosted in the opposite direction. However, direct measurement of the W rapidity is a challenging task because of the unknown component of the outgoing neutrino momentum. Therefore we measure the asymmetry in the pseudo rapidity of the electrons and positrons, which is defined as following.

$$A(\eta_l) = \frac{d\sigma_+/d\eta_l - d\sigma_-/d\eta_l}{d\sigma_+/d\eta_l + d\sigma_-/d\eta_l}. \tag{3}$$

In 170 pb^{-1} of CDF Run II data, we select events with one tight electron candidate with high transverse energy (> 25 GeV) in the central and forward regions of the detector ($|\eta| < 3$) and with high missing transverse energy (> 25 GeV) from the neutrino. We correct for the mis-identification of the lepton charge, fake electrons from jets and other backgrounds which bias the asymmetry. We divide the transverse energy (E_T) of the leptons into two ranges, one with $25 < E_T < 35$ GeV and the other with $35 < E_T < 45$ GeV, for increased sensitivity. W asymmetry measurements drive the determination of d(x)/u(x) in standard PDF fits. The agreement with current PDFs indicates that this result is consistent with but more precise than Run I measurements (Fig. 2).

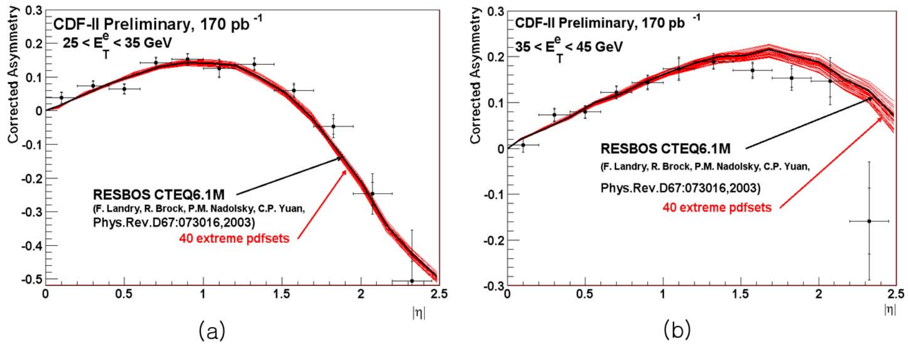


Fig. 2. *(a) W charge asymmetry of low E_T events. (b) W charge asymmetry of high E_T events. Compared with the uncertainy band of PDF.*

4. Results on Search for New Phenomena

W and Z production is sensitive to new phenomena because of the clean signal and low backgrounds. Many models predict deviations in the differential cross sections $d\sigma/dM_{l\bar{l}}$ and $d\sigma/d\cos\theta^*$. The CDF and D0 collaborations have determined limits to various Z' models, including E(6), Littlest Higgs, Technicolor and so on. Extra dimension theories and Supersymmetry theories can also be probed in the W and Z channels. We present the search for the E(6) model Z' [5] at CDF in the dielectron and dimuon channels. The D0 results on new phenomena are presented in a separate article elsewhere in these proceedings [6].

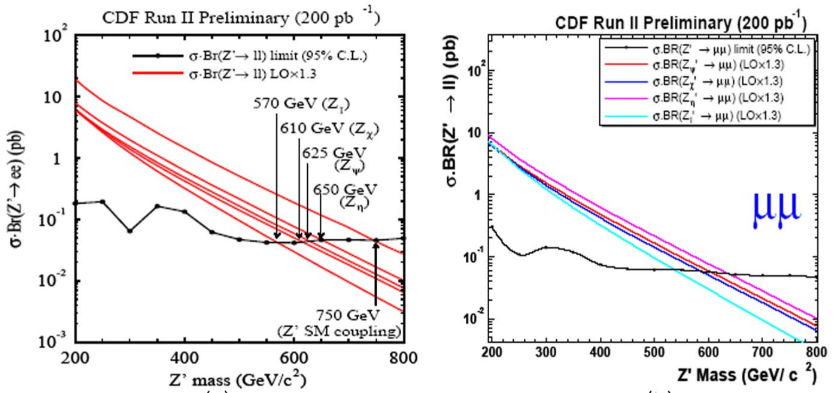
In 200 pb^{-1} of CDF Run II data we select dielectron events with two isolated electron candidates with transverse energy larger than 25 GeV. We select dimuon events by requiring two isolated muon candidates, and with transverse momentum larger than 20 GeV/c, one in the region of $|\eta| < 1.0$ and the other in $|\eta| < 1.5$. Sources of the background that produce dilepton include Standard Model Drell-Yan production, diboson production and top quark pair production. We also expect fake dilepton from processes such as W with jets, dijets and cosmic rays. We estimate these backgrounds from the data wherever possible, and from Monte Carlo simulation otherwise.

Different models predict distinct angular distributions of the final state leptons which affects the acceptance as a function of the invariant mass of the lepton pairs. Therefore the models of new physics can alter the measurement of the cross section.

Mass limits for E(6) model Z' from the dielectron and dimuon channels are shown in Table 1 and Figure 3. The sensitivity in Run II is significantly higher than that of Run I.

Table 1. CDF result on E(6) model Z' search.

	Mass limit @95% CL (GeV/c^2)	
	Dielectron	Dimuon
Run I	640	590
Run II	750	735



(a) (b)

Fig. 3. *(a) Limits on E(6) model Z' in dielectron channel. (b) Limits on E(6) model Z' in dimuon channel.*

5. Conclusion

We survey Run II CDF and D0 results on Drell-Yan production, and find them in good agreement with Standard Model predictions. These results can limit non-Standard Model contributions to Drell-Yan production and probe proton PDFs.

References

1. The CDF II Detector Technical Design Report, Fermilab-Pub-96/390-E.
2. T. LeCompte and H.T. Diehl, *Annu. Rev. Nucl. Part. Sci.* 50:71-117 (2000).
3. S.D. Drell and T.-M. Yan, Phys. Rev. Lett. **25**, 316, 902 (E) 1970; Ann. Phys. (N.Y.) **66**, 578 (1971).
4. Greg Veramendi *et al*, Measurement of Forward-Backward Charge Asymmetry of Electron-Positron Pairs, to be submitted to PRD.
5. J.L. Hewett and T.G. Rizzo, Phys. Rept. **183**, (1989) 193.
6. R. Hooper